

Susceptibility to distraction during analogical reasoning in schizophrenia

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ABSTRACT

Proportional analogies between four objects (e.g., a *squirrel* is to *tree* as a *golden fish* is to? *aquarium*) were examined in 30 schizophrenia patients and 30 healthy controls. Half of the problems included distracting response options: remote semantic associates (*fishing rod*) and perceptually similar salient distractors (*shark*). Although both patients and controls performed fairly accurately on the no-distraction analogies, patients' performance in the presence of distractors was distorted, suggesting deficits in attention and cognitive control affecting complex cognition. Finally, although education, fluid intelligence, and interference resolution strongly predicted distractibility in the control group, in the schizophrenia group susceptibility to distraction was unrelated to these markers of general cognitive ability, implying an idiosyncratic nature of reasoning distortions in schizophrenia.

1. Introduction

Schizophrenia is a chronic mental disorder traditionally primarily related to positive and negative symptoms, such as hallucinations, delusions, disorganised speech, bizarre behaviour, emotional flattening, and social withdrawal. Nonetheless, cognitive deficits—which for decades have attracted relatively little attention as they are less pronounced than psychotic symptoms—have in recent years attracted considerable interest, being recognised as a central feature of schizophrenia. Cognitive impairments are *primaevae* deficits in this mental disorder and in many cases are present well before the onset of any other symptoms (Bora et al., 2014; Davidson et al., 1999; Mohamed et al., 1999). The most prevalent deficits include dysfunctions of attention, executive function, language, verbal learning, and memory (Bilders et al., 1992; Bowie and Harvey, 2006; Heinrichs and Zakzanis, 1998; Riley et al., 2000). Cognitive deficits are the best predictor of functioning across a number of outcome domains and patient characteristics (for reviews see Green, 1996; Green et al., 2000).

A frequently reported symptom experienced by patients suffering from schizophrenia after admission consists of ineffective coping with distraction (Freedman and Chapman, 1973), which reflects weakened filtering of salient but irrelevant information (i.e., distractors) accompanied by deficits in focusing attention on task-relevant but not necessarily salient targets (see MacLeod, 1991). Ability to cope with perceptual distraction is often measured with digit-span and word-span tasks using a neutral and a distractor condition. In the neutral condition, subjects are asked to listen to a tape and repeat a list of digits or

words read by a female voice. In the distractor condition, a male voice is also recorded between the target digits. Subjects are instructed to ignore digits read by the male voice. Patients' performance on this task is significantly hindered compared with that of healthy controls (Addington et al., 1997; Green and Walker, 1986; Rund, 1989). Addington et al. (1997) further investigated the relationship between digit-span scores and schizophrenia symptoms and concluded that performance remains stable over time regardless of changes in symptoms. This is in line with other data showing that cognitive deficits are highly intra-individually stable over time (Harvey et al., 1990).

Furthermore, a comprehensive meta-analysis of the Stroop interference effect (i.e., naming an incongruent colour of a word meaning a colour; e.g., 'blue' printed in red ink) in schizophrenia underlined deficits in cognitive inhibition that partly explain impairments in executive functions in this mental disorder (Westerhausen et al., 2011). A review including another two paradigms—negative priming and the flankers—also confirmed inhibition abnormalities in schizophrenia in the presence of distractors (Chieffi et al., 2015).

In addition, context processing—the mechanism responsible for context representation and maintenance—is profoundly impaired in schizophrenia (for a review see Barch and Braver, 2005). Context is defined as “information that must be ‘actively’ held in mind in a form that allows it to be used to mediate task appropriate behavior” (p. 124). Context allows a task instruction to be applied that directs behaviour towards achieving a solution (e.g., in the Stroop task the context is to ignore the word and name the colour). Additional evidence on the reduced ability to use a context in schizophrenia is provided by extensive

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neuroimaging research using the N400 component, which is an indicator of the degree to which a given stimulus (e.g., a current word) is consistent and related to a preceding context (e.g., another word, the whole sentence, or the entire discourse) (e.g., Condray et al., 1999; Nestor et al., 1997; Niznikiewicz et al., 1997; Sitnikova et al., 2002).

However, it is not clear whether the proneness to distraction in schizophrenia observed in all these relatively simple tasks also affects complex cognitive processing such as reasoning and problem solving; in these, top-down processing plays a crucial role, so the presence of distractors in the environment may be less disruptive. Presumably, even if the participant's attention is initially captured by a distractor, in the case of more complex and longer lasting processes effective cognitive control may lead the participant to revise his or her course of reasoning back to the current goal and eventually to ignore the distractor. However, since schizophrenia patients have deficits in context processing, it is also possible that they lack the ability to reject distractors that are present in a complex task even if they have a substantial amount of time in which to do so. Unfortunately, studies that have examined whether and to what extent schizophrenia patients suffer from distraction in reasoning and problem solving are scarce.

1.1. Distraction during analogy-making in schizophrenia

The present study focused on schizophrenia patients' performance on one type of complex cognitive process: reasoning by analogy. Such reasoning is prevalent in everyday life and acknowledged to underlie productivity, compositionality, and flexibility in human thinking (Hofstadter, 2001). To make a successful analogy one must identify the structural correspondence between objects or situations that are inter-related (see Gentner, 1983; Holyoak, 2012) and at the same time very often ignore featural similarities (e.g., having the same parts or attributes) or strong semantic associations between them (e.g., belonging to the same category; Markman and Gentner, 1996). Should the latter factors, rather than structural correspondence, drive the (in which case, probably incorrect) analogy, then it is highly likely that the reasoner will first become distracted by these irrelevant but usually enticing and prepotent factors, and second, will fail to control their course of reasoning by performing a structural mapping of analogues (which, especially in remote analogies, share neither features nor semantics).

That semantic distractors may be especially challenging for schizophrenia patients is suggested by research on such patients' distortions of semantic processing and abnormal associations distribution (see McCarley et al., 1999). For instance, Maher (1983) suggested that a heightened effect of semantic priming may result in the associative intrusion observed in the speech of schizophrenia patients. Presumably, greater proneness to following automatically strong semantic associations may hinder the ability to avoid semantic distractors in the reasoning process.

Analogical tasks comprise highly familiar content and relations, which makes them ecologically valid to a large extent. As such, they seem better suited for research on clinical groups than do more artificial and formal tasks such as logical inferences (e.g., Contreras et al., 2016; Kemp et al., 1997) and probability judgments (e.g., Averbach et al., 2011; Freeman et al., 2014; Moritz and Woodward, 2005). There are two main paradigms in studying reasoning by analogy: the four-term analogy task and the scene analogy task.

In four-term (A:B::C:D) analogies (Alexander et al., 1987; Goranson, 2002; Goswami and Brown, 1990), a relation linking A and B must apply to C and the to-be-found D. For example, in the analogy 'squirrel is to tree as golden fish is to?', the relation is 'typical habitat' and the valid conclusion is 'aquarium'. The introduction of distractors into the response bank in four-term analogies is common practice in studies of analogical reasoning (see Holyoak, 2012). Usually, there are four possible answers: a correct one; one or two unrelated objects; and one or two distractors (perceptual and/or semantic). This kind of design is used to assess the effectiveness of reasoning by analogy in the presence

of distractors in various sub-fields, such as clinical research (e.g., Krawczyk et al., 2008, 2010) and developmental psychology (e.g., Gladys et al., 2017; Goswami and Brown, 1990; Thibaut and French, 2016).

In the case of scene analogies, subjects are asked to indicate an object in one scene that matches an object highlighted in another scene (Richland et al., 2006). For instance, a dog chasing a cat chasing a mouse in one scene would be mapped onto a woman chasing a boy chasing a girl in another scene.

Despite the wide use of both paradigms in basic research, employing analogical tasks in schizophrenia has been rare, even though such tasks could substantially increase our knowledge of complex cognition in this mental disorder. One exception is the study by Simpson and Done (2004), who examined the solution transfer from a military attack problem to a tumor radiation problem (Gick and Holyoak, 1983) and reported that 17 of their schizophrenia patients missed the analogical correspondence between the problems. In addition, Krawczyk et al. (2014) found pronounced errors in drawing scene analogies in 13 schizophrenia patients; nevertheless, the patients' performance was still very accurate (84.6% correct vs. 94.4% for healthy controls), even though 12 out of the 24 scene analogies were relatively complex. This latter study indicates that the natural framing of basic analogy tasks means that they load only mildly on the cognitive system (even a dysfunctional one) and are well suited to introducing targeted experimental manipulations aimed at tracing specific cognitive deficits.

Specifically, one influential hypothesis claims that undeveloped (in children) and distorted analogical reasoning (in normal ageing and clinical subpopulations) is rooted in cognitive control dysfunctions causing proneness to distraction (see Barkley, 1997; Goswami and Brown, 1990; Krawczyk et al., 2010; Robin and Holyoak, 1995). For instance, when mapping the chasing/chased cat scene onto a scene in which a dog chased by a boy is chasing a cat, children below five years of age usually incorrectly map the two cats together and the two dogs together, demonstrating difficulty in inhibiting perceptual/semantic similarity and using relational roles to map the dog onto the cat (Richland et al., 2006). Similar deficits have been reported for frontal lobe patients (e.g., Krawczyk et al., 2008; Morrison et al., 2004).

However, the only research that has examined distractors in an analogical task in schizophrenia is the above-mentioned Krawczyk et al. (2014) study. Here, distraction was introduced into half of the scene analogy problems, so that either an object or an actor playing a role in the key relation in one scene was also placed in the other scene. Unfortunately, a distracting object/actor was also placed outside the key relation in the latter scene (sticking with the chasing/chased cat example, the chased mouse from one scene was sitting and only observing the boy chasing the dog chasing the cat in the other scene), so it may have been largely ignored during the analogical reasoning process.

1.2. Distortions of complex cognition in schizophrenia and general cognitive ability

There is ongoing debate on whether dysfunctions of complex cognition in schizophrenia can or cannot be explained away simply in terms of lower general cognitive ability (general and/or fluid intelligence; see McGrew, 2009). In this view, the disease is associated with an overall decline in reasoning and problem-solving performance, especially on novel abstract problems, as revealed by typical intelligence tests such as the Raven Progressive Matrices.

Research on both deductive and inductive reasoning tasks has yielded inconclusive evidence: some reports have suggested that cognitive dysfunctions are specific to schizophrenia and cannot be (fully) attributed to patients' lower intelligence (see Crawford et al., 1993; Martin et al., 2015; Niznikiewicz et al., 1997; Reichenberg and Harvey, 2007; Simpson et al., 1998; Sørensen et al., 2006; Wilk et al., 2005); whereas other studies have found that accounting for intelligence reduces or even eliminates schizophrenia-related declines in performance

(see Freeman et al., 2014; Jolley et al., 2014; Mirian et al., 2011). However, to date no study has tackled this issue with regard to analogical reasoning; specifically, whether distractibility is related to intelligence remains unknown.

1.3. Objectives of the study

Consequently, the present study applied a battery of four-term analogy problems in neutral and distraction conditions to patients and healthy controls in order to answer three key questions: (i) are patients especially prone to distractibility during analogical reasoning?; (ii) are they more vulnerable to distractors that match the targets both categorially and perceptually than to distractors associated only semantically?; and (iii) can individual differences in patients' distractibility be explained by variance in general reasoning ability as well as executive control ability, or do these differences instead reflect an idiosyncratic deficit?

In light of the existing literature, we expected to observe a lower ability to avoid semantic distractors as a result of impaired cognitive inhibition and deficits in maintaining relevant context (in this case, the analogy) to solve a problem. The relation between distractibility and cognitive ability was an open question.

2. Method and materials

2.1. Four-term analogies

Each of 64 analogies had the aforementioned format A:B::C:D, in which item D was absent. In the first 32 problems, the response option set contained no distractors, while the remaining 32 problems had two distractors among the possible responses. The salient distractor was an object that belonged to the same semantic category as object C and was also perceptually similar to it (e.g., a shark is an example of a salient distractor for a fish as it belongs to the same semantic category and is similar perceptually in terms of shape). The remote distractor was only semantically associated with C; it did not resemble it perceptually (e.g., a fishing rod is an example of a remote distractor for a fish). Analogies across the two 32-item sets were matched on number of living objects and type of analogical relation between the source and the target. To make the task less monotonous, analogies switched between pictorial (items 1–16 and 33–48) and verbal (items 17–32 and 49–64) forms. Fig. 1 presents a sample item.

The mean error rate for the no-distraction problems was low both for the controls (1.5%) and for the patients (8.0%), matching Krawczyk et al.'s (2014) findings. The majority of patients made no error (eight people), or just one (six people), two (eight people), three (two people), four (two people), or six (one person) errors. Only the remaining three patients committed from eleven to fourteen errors. As many as 23 controls made no error, five made one error, one made two errors, and only one person made eight errors. Thus, because of the pronounced ceiling effects for both controls and patients, performance on the no-distractor problems was not analysed further. However, to control statistically for analogy-making performance in the neutral condition (when the distractors were absent in the response options), which appeared to be hindered in three patients and one control (i.e., 25% or more errors), the dependent variable (distractibility) was defined as individual performance on the analogy problems with options including distraction minus performance on the problems with no distracting option. The latter performance captured potential general cognitive, social, affective, and medical factors unrelated to distractibility, so the resulting variable was specific to the distraction itself present in the response options. Specifically, distractibility was computed as the difference between the proportions of errors committed on problems with and without distraction and showed how much individual performance deteriorated when distractors were present in the response options. Another variable, vulnerability to distractor salience, reflected the kind

of errors made regardless of actual performance level. It was defined as the ratio of salient distractors selected by a participant to the sum of both salient and remote distractors selected, reflecting how prone the participant was to picking the salient distractors.

2.2. Reasoning ability

This task involved 18 selected problems from the above-mentioned hallmark test of fluid intelligence—i.e., Raven's Standard Progressive Matrices (hereafter referred to as the Raven). Each problem was a visual geometric pattern with one cell missing. Participants were asked to choose one out of six or eight response options (depending on the problem) so that it filled the missing cell according to the hidden rule(s) governing the pattern. The score was the proportion of incorrectly solved problems (*Raven errors*).

2.3. Interference resolution

This task involved two parts. The word-reading part consisted of reading aloud as quickly as possible 50 words, each describing a colour, that were printed in black on one A4 page (5 words per row). The colour-naming part involved naming as quickly as possible the colour in which another 50 words were printed; these words were presented in the same layout but this time their meaning (the colour name) was incongruent with their ink colour (e.g., the word 'red' was printed in green). All the words were in Polish—the native language of all the participants. The dependent variable (*Stroop interference*) was the difference between the time taken to name the colours and the time taken to read the words (subtraction controlled for differences in processing speed).

2.4. Participants

The experiment involved 34 healthy controls as well as 30 inpatient individuals who met the ICD-10 criteria for schizophrenia. The patients' condition was examined by a psychiatrist and a clinical psychologist, according to whom the patients showed neither signs of delusion at the time of the experiment nor any profound thought disorder that would impede communication or task comprehension. All the patients were being medicated with second-generation antipsychotics. At the time of participating, they had spent six to eight weeks on the ward since being admitted to hospital. Their condition was assessed as stable. Controls were drawn from non-psychiatric patients and from the general population via word of mouth. All the participants were informed about the right to stop the experiment at any time at will. All provided informed consent to participate. The entire procedure was approved by the local Ethics Committee. The data of two controls were missing, while that of two others who had gone the furthest in their education were excluded to achieve a better match between the groups.

Overall, there were 13 female and 17 male patients and 19 female and 11 male healthy controls, making this the largest sample to date in research on distraction during reasoning by analogy in schizophrenia. The mean time that had elapsed from the patients' schizophrenia diagnosis was $M = 10.0$ years ($SD = 8.1$, range 1–31). Age did not differentiate the patients ($M = 35.3$ years, $SD = 9.9$, 24–55) from the controls ($M = 35.3$ years, $SD = 7.7$, 21–51), $t(58) = 0.03$. Education slightly but not critically differed between the patients ($M = 13.3$ years, $SD = 2.7$, 8–17) and the controls ($M = 15.2$ years, $SD = 2.6$, 11–18), $t(58) = 2.74$. The patients were less accurate on the Raven ($M = 34.4\%$ errors, $SD = 17.3\%$, 5.5–72.2%) than were the controls ($M = 11.5\%$ errors, $SD = 11.7\%$, 0–38.9%), $t(58) = 6.07$. The patients also took more time to name the colours ($M = 45.4$ s, $SD = 19.8$ s, 21–118 s), compared with the controls ($M = 28.9$ s, $SD = 10.0$ s, 10–45 s), $t(58) = 4.27$.

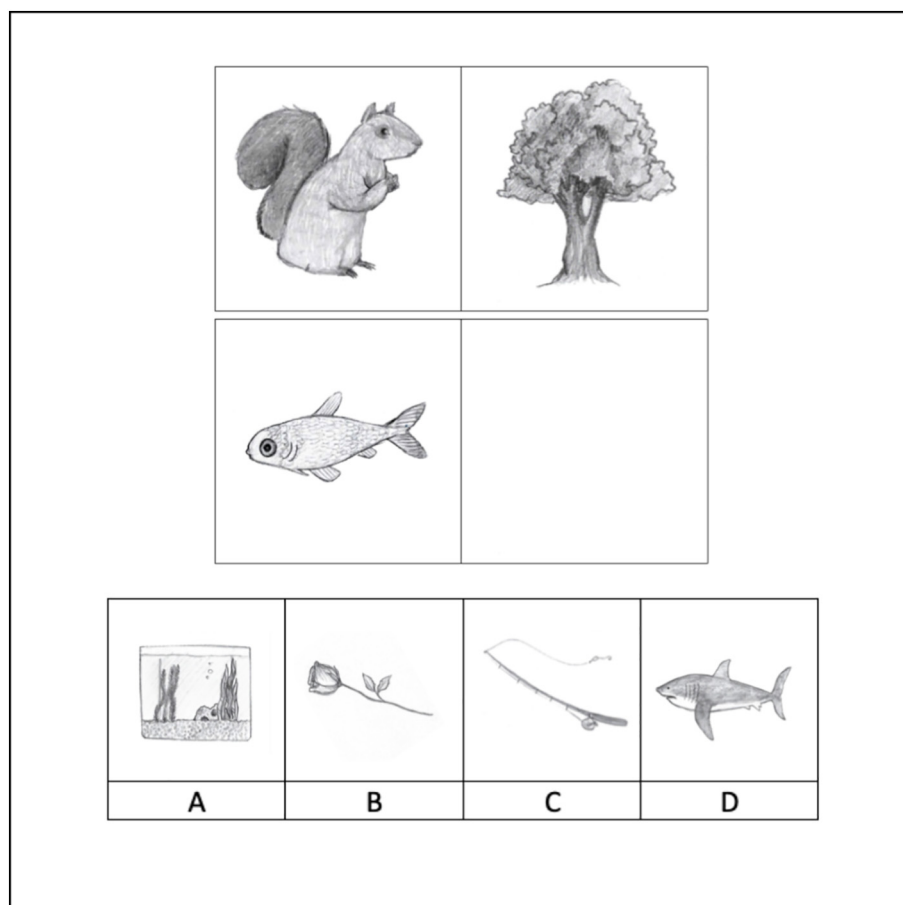


Fig. 1. An example four-term analogy. Response options include: A (an aquarium) - the correct response, B (a rose) - an unrelated object, C (a fishing rod) - a remote distractor related semantically, D (a shark) - a salient distractor belonging to the same semantic category and perceptually similar.

2.5. Procedure

All materials used in this study, except for the 'colour-naming' task, were printed in black ink on a white A4 sheet of paper. Each task was preceded by written instructions. The researcher provided additional verbal help where necessary. To make the reasoning by analogy task clear, the rules were explained to all the participants using an exemplary exercise. Next, the participants attempted to solve a training problem by themselves. The same training was used with the Raven. Participants indicated their response by saying its letter/number index aloud. If they selected the correct response, the experiment commenced. Otherwise, the experimenter repeated the instructions, pointing to the right response, and only then proceeded to the experiment. The entire session lasted about 30 min.

2.6. Data treatment and analysis

No data cells were missing. Bayes Factor (BF) was used to test differences in means between the patients and the controls. BF assessed the ratio of posterior likelihood in favour of the hypothesis that the patients' performance would be worse than that of the controls, given the evidence. Although BF implicates no fixed 'significance level',

typically BF values exceeding 3.0/10.0 suggest reliable/strong evidence in favour of the hypothesis being tested, those below 0.33/0.10 reliably/strongly suggest no effect, and those in between are considered to be inconclusive (Kass and Raftery, 1995). As larger values of demographic variables (age, distractibility, years of education – reversed) indicated worse outcomes, positive correlations among the variables were expected. All calculations were carried out in JASP software (jasp-stats.org). In line with the scarcity of existing evidence, the default value of prior parameter was adopted, assuming the equal, a priori likelihood of both hypotheses tested.

3. Results

Table 1 presents the error rates and standard deviations for all four conditions of the four-term analogy task, separately for the schizophrenia patients and the control group.

3.1. Distractibility

Fig. 2a presents the distribution of the distractibility index for each group. The patients' mean distractibility ($M = 25.1\%$ errors, $SD = 15.2\%$, range 0–62.0%) was significantly higher than the mean

Table 1
Error rates (and standard deviations) for the four conditions of the four-term analogy task.

	Pictorial without distraction	Verbal without distraction	Pictorial with distraction	Verbal with distraction
Patients	8.3% (11.7)	8.1% (13.4)	35.8% (18.5)	31.6% (19.6)
Controls	1.2% (4.7)	1.9% (4.9)	14.3% (20.4)	7.8% (14.2)

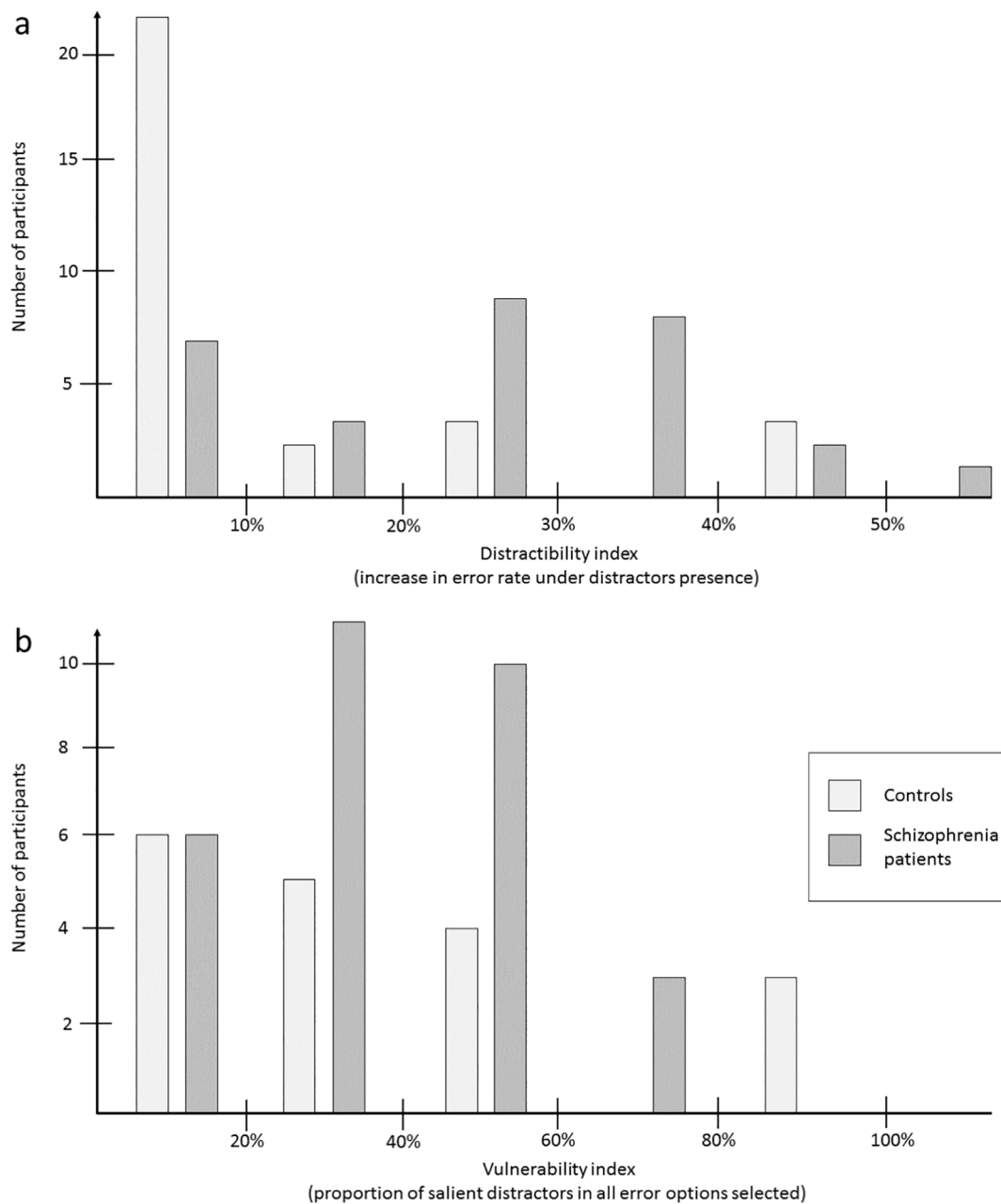


Fig. 2. (a) The distributions of distractibility index (the difference in error rate between the analogies with and without distraction) for the groups of 30 controls vs. 30 patients of schizophrenia. (b) The respective distributions of index of vulnerability to salient distractors (the proportion of error options matching both semantically and perceptually, in all error made). Note that the latter index was computed for only the 18 controls who made at least one error (all the 30 patients made errors).

distractibility of the controls ($M = 9.4\%$ errors, $SD = 14.3\%$, 0–50%), $BF_{10} = 360.9$, Cohen's $d = 1.08$.

In order to exclude the possibility that the distractibility effect was somehow affected by participants who generally performed poorly on the task, in an additional step the three patients and the one control who did not meet the $< 25\%$ errors criterion on the trials without distraction were excluded from the analysis. The effect was barely affected by excluding these outliers, with the patients ($M = 26.4\%$ errors) still much more distractible than the controls ($M = 9.1\%$ errors), $BF_{10} = 336.6$, Cohen's $d = 1.09$.

3.2. Vulnerability

Fig. 2b presents each groups' distributions of the index of

vulnerability to distractor salience. Values were available for 18 controls only, because 12 controls scored null distractibility (see Fig. 2a). Mean vulnerability was comparable between the patients ($M = 36.5\%$ salient errors, $SD = 19.7\%$, 0–72.0%) and the controls ($M = 34.9\%$ salient errors, $SD = 33.3\%$, 0–100%), $BF_{10} = 0.300$, $d = 0.06$. Again, the analysis excluding the four outlying participants yielded virtually the same outcome ($M = 35.6\%$ vs. $M = 32.0\%$ salient errors for patients and controls respectively) $BF_{10} = 0.331$, $d = 0.08$.

3.3. Correlations

Table 2 presents the matrix of Pearson correlations, separately for each group. Four patterns of results emerged. First, in the patients, education (reversed), Stroop interference, and vulnerability were

Table 2
The matrix of Pearson correlations between all variables examined in the study.

	1.	2.	3.	4.	5.	6.
1. Age	–	0.586	0.513	0.470	0.406	–0.251
2. Education (reversed)	–0.043	–	0.773	0.530	0.654	0.271
3. Raven errors	0.284	0.475	–	0.494	0.831	–0.035
4. Stroop interference	0.308	0.350	0.256	–	0.476	0.250
5. Distractibility	0.210	0.116	0.219	0.268	–	–0.103
6. Vulnerability	0.332	0.345	0.433	–0.019	0.193	–
7. Years from diagnosis	0.610	0.397	0.271	0.446	0.268	0.373

Note. Data for the control group above the diagonal, data for the schizophrenia patients below the diagonal. N = 30 for each group, except for the vulnerability index in the control group (N = 18). Correlations with BF surpassing 2.0 marked with bold font.

significantly predicted by the time that had elapsed since their schizophrenia diagnosis (e.g., it accounted for 20.2% of the variance in interference). Second, the variables relating to general cognitive ability—i.e., age, education (reversed), Raven errors, and Stroop interference—were more closely mutually correlated in the controls, as indicated by their visibly higher loadings on the principal component (0.776, 0.893, 0.860, 0.745, 67.4% of the variance explained by the component), than in the patients (0.530, 0.721, 0.767, 0.698, 46.9% of the variance explained); suggesting, as predicted, a certain amount of distortion in the structure of cognitive abilities in the patients (see Martin et al., 2015). Third, the controls' distractibility was significantly correlated with age, education (reversed), Raven errors, and Stroop interference; furthermore, all these correlations were actually driven by Raven errors, which explained 68.9% of the variance in distractibility (and was its only significant predictor in the regression model). In contrast, none of these variables significantly predicted distractibility in the patients (e.g., Raven errors explained as little as 4.8% variance). Tested formally using a permutation test, the amount of variance in distractibility explained by the Raven in the controls was significantly larger than the corresponding amount explained by the Raven in the patients, $\Delta r = 0.612$, $p = .0004$, one-tailed. Fourth, exactly the reverse pattern could be observed for vulnerability: 18.5% of its variance was significantly predicted by the Raven errors made by the patients, whereas it accounted for null variance in the controls. Possibly because of the low number of vulnerability values for the controls, the $\Delta r = 0.468$ difference only tended to significance according to the permutation test, $p = .059$, one-tailed. Fig. 3 illustrates the relationships between the Raven errors and distractibility and vulnerability in the two groups.

4. Discussion

Thirty patients displayed substantially greater distractibility during analogical reasoning than did the thirty controls, more frequently selecting incorrect options which contained either a salient (a perceptually similar object from the same category as the to-be-matched analogue) or a remote (a perceptually different but semantically related object) distractor. At the same time, both groups scored high on analogies that did not contain distractors, suggesting that selecting the relationally matching target was quite easy when invalid options were unrelated to the to-be-matched analogue. However, despite the former's greater proneness to distraction, the patients and the controls were similarly largely invulnerable to salient distractors, with both groups selecting twice as many remote distractors (relatively more 'reasonable' errors to make) as salient ones. Finally, the pattern of correlations revealed different origins of the distractibility in the two groups. General cognitive ability was a direct predictor of the controls' distractibility, with over two-thirds of its variance explained by performance on the Raven test. In contrast, the patients' higher distractibility was not related to any variable, not even to the length of time since they had been

diagnosed with schizophrenia, suggesting the idiosyncratic nature of their distractibility. The pattern for vulnerability was reversed: it covaried with cognitive functioning only in the patients. However, the lack of correlation in the control group could have been affected by the relatively low number of people (Freeman et al., 2014) who made errors in analogies as well as by the overall low number of errors committed (106). Summing up, two patterns of correlations seem statistically meaningful: (i) the Raven errors, age, education (reversed), and interference predicted distractibility in the controls but not in the patients, (ii) however, for the patients these measures nicely predicted vulnerability.

The present results suggest that higher distractibility in schizophrenia patients negatively affects their complex cognition in the presence of semantically associated objects. A stronger distractibility in analogical reasoning on semantic material in schizophrenia may arise through two dysfunctional mechanisms. First, susceptibility to intrusions caused by semantic associations may increase the probability that a distractor rapidly attracts attention before that attention can be directed at the target (and so it is not). This mechanism could pertain to bottom-up processing resulting in distorted problem representation affecting the course of reasoning. The second mechanism taps more complex processing. Specifically, dysfunction in context processing in schizophrenia leads to an inability to validate conclusions that are incompatible with the current goal and the relevant context (Barch and Braver, 2005; Barch et al., 2001). In the case of four-term analogies, the context is not complete until the relation between A and B is considered. Schizophrenic patients may be prone to basing their responses solely on the option's semantic relationship to the C term, ignoring the context. It is worth mentioning that there was no time pressure in the reasoning task, so the opportunity for participants to correct their course of reasoning was not restricted. According to the model proposed by Barch and Braver (2005) and based on numerous prior studies (Barch et al., 2001; Braver et al., 1999; Braver and Cohen, 1999), deficits of context processing—a component of more general deficits in cognitive control—underlie disrupted performance on a broad array of task domains. Disturbances in the dopaminergic mechanisms in the dorsolateral prefrontal cortex play a central role in this model. Lesh et al.'s (2011) model explaining impaired higher cognition in schizophrenia also assumes that deficits in cognitive control resulting from dysfunction in the prefrontal cortex play a central role.

That both groups were generally not vulnerable to salient distractors, and that vulnerability covaried with general cognitive ability only in the case of schizophrenia patients, is very informative. It supports the idea that distractibility during analogical reasoning is rooted in more bottom-up mechanisms of susceptibility to improper semantic associations, and that the primary criterion for a stimulus to be a distractor is to share semantics with the target. In contrast, the incorrectness of sheer perceptual similarity is obvious and can be relatively easily rejected. Thus, actual distractibility depends upon semantic associations, reflecting abnormalities in the semantic network. The fact that vulnerability was greater only in patients with low general cognitive ability may suggest that only very profound cognitive disorder leads to substantial susceptibility to perceptual similarity.

A crucial result concerns the null correlations between distractibility and other variables in schizophrenia where significant correlations were observed for the healthy controls. Effective reasoning relies on the coordinated functioning of several brain regions (Krawczyk et al., 2008). In light of the heterogeneity of cognitive deficits (Joyce and Roiser, 2007) and the structural brain abnormalities in schizophrenia (e.g., Glahn et al., 2008; Harrison, 1999), it is unlikely that distorted reasoning by analogy could be explained entirely by a single factor, such as general intelligence. In contrast, null correlations between the variables suggest substantial disintegration of the structure of cognitive abilities. These findings also accord with data showing that fluid intelligence does not explain impaired performance on a broad battery of executive function tests (Martin et al., 2015).

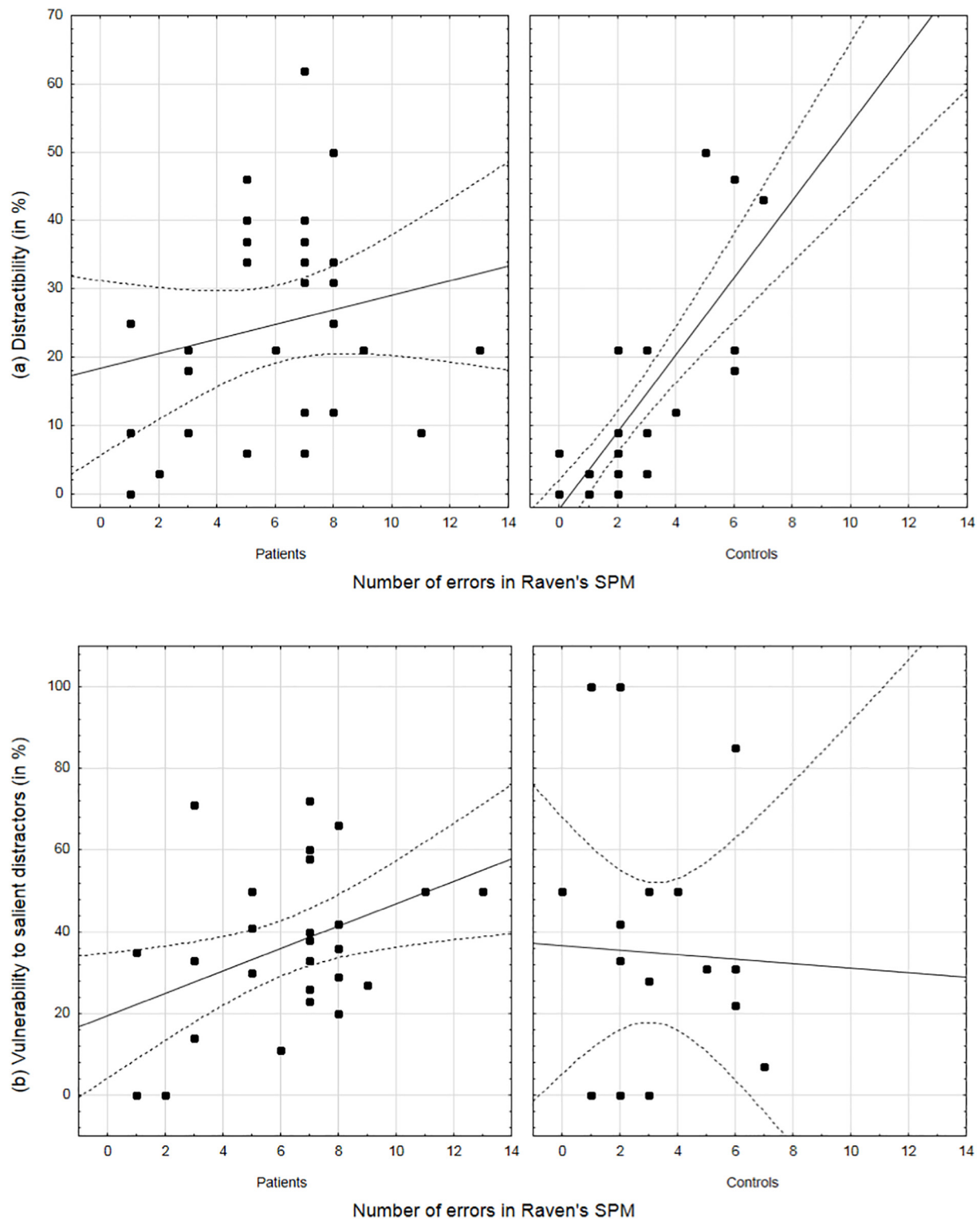


Fig. 3. (a) Scatterplots presenting the significantly different relationship between the number of errors committed in Raven's SPM test and the distractibility index (increase in error rate under distraction presence) in the schizophrenia patients vs. the healthy control group. (b) Analogical, but opposite, difference in relationship between the two groups for the vulnerability index (proportion of salient distractors in all error options selected). Black solid line indicates the regression line, dashed lines reflect the 95% confidence belts.

Finally, no relationship was found between distractibility and the length of time patients had been diagnosed as having schizophrenia, in accordance with [Zipursky et al.'s \(2013\)](#) findings contesting the idea of progressive deterioration of cognitive functioning during the course of the illness. [Mohamed et al. \(1999\)](#) also concluded that cognitive deficits

are intrinsic and do not depend on institutionalisation history or illness duration.

5. Conclusion

The current study provides new insights into the nature of distractibility affecting complex cognition in schizophrenia. It underscores the highly negative impact of distractors on patients' analogical reasoning and points to the disintegration of their structure of cognitive abilities. Null links with other cognitive functions indicate that distractibility is a specific disorder that should be assessed regardless of other dysfunctions in order to diagnose validly the cognitive condition of patients suffering from schizophrenia. The present results support the view that cognitive dysfunctions in schizophrenia are serious and complex.

Contributors

Both authors designed, conceptualized, and planned the study. H. Kucwaj collected the data. A. Chuderski undertook the statistical analysis. Both authors contributed to and have approved the final manuscript.

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Declaration of competing interest

None.

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